**Testi in italiano**

**Lingua insegnamento**

Inghese

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**Testi di riferimento**

### Obiettivi formativi
L'obiettivo del corso è fornire allo studente la capacità di comprendere ed applicare le regole di base della teoria della decisione e della stima, e in particolare:
- i test statistici nel decidere tra diverse ipotesi
- la struttura del decisore ottimo nel contesto delle trasmissioni numeriche.
- i principali stimatori di uso comune
- la struttura dei filtri ottimi nel contesto delle trasmissioni numeriche.

Le capacità di applicare le conoscenze sopra elencate risultano essere in particolare:
- progettare ed analizzare le prestazioni del blocco di decisione nei ricevitori per trasmissioni numeriche
- progettare ed analizzare le prestazioni dei blocchi di stima dei parametri di segnale nei ricevitori per trasmissioni numeriche.

### Prerequisiti
Vedi testo inglese.

### Metodi didattici
Lezioni teoriche per un totale di 63 ore ed esercitazioni per un totale di 9 ore. Esercizi assegnati per casa.

### Altre informazioni
Vedi testo inglese

### Modalità di verifica dell'apprendimento
Esami solo orali. Vedi dettagli nel testo inglese

### Programma esteso
Vedi Testo Inglese

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### Testi in inglese

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2.1 Fisherian estimation
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2.1.2 Cramer Rao Lower Bound
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2.2 Bayesian estimation
2.2.1 Minimum Mean Square Error estimation
2.2.2 MAP estimation
2.2.3 Linear MMSE estimation
2.2.4 Spectral Factorization and Wiener Filtering

Testi di riferimento

Reference Textbooks

Part I: Detection

Part II: Estimation

Obiettivi formativi

Objective of the course is to provide the student with the ability to understand and apply the basic rules of detection and estimation theory, and in particular:
- to apply the most common statistical tests in deciding among different hypotheses
- to synthesize the structure of the optimal receiver and analyze its performance in the context of digital transmissions
- to apply the most common statistical estimators
- to synthesize the structure of the optimal filters and analyze their performance in the context of digital transmissions.

The abilities in applying the above-mentioned knowledge are in particular in the:
- design and performance analysis of the decision block in digital receivers
- design and performance analysis of the parameter-estimation blocks in digital receivers

Prerequisiti

Pre-requisites

Entry-level courses in probability theory and Fourier analysis for stochastic processes, such as those normally offered in the corresponding 3-year Laurea course, are necessary pre-requisites for this course.

Metodi didattici

Teaching Methodology

Classroom teaching, 63 hours. In-class problem solving, 9 hours. Homeworks assigned weekly.

Altre informazioni

Office Hours

Monday 11:30-13:30 (Scientific Complex, Building 2, floor 2, Room 2/19T).

Modalità di verifica dell'apprendimento

Exams

Oral only, to be scheduled on an individual basis. When ready, please contact the instructor by email at alberto.bononi[AT]unipr.it by specifying the requested date. The exam consists of solving some proposed exercises and explaining theoretical details connected with them, for a total time of about 1 hour. You can bring your summary of important formulas in an A4 sheet to consult if you so wish. Some sample exercises can be found on the course website. To get userid and password, please send an email to alberto.bononi[AT]unipr.it from your account nome@studenti.unipr.it.
Syllabus (every class = 2 hours)

CLASS 1:
First hour: Course organization, objectives, textbooks, exam details. Sneaky preview of the course, motivations, applications. Second hour: basic probability theory refresher: total probability, Bayes rule in discrete/continuous/mixed versions, double conditioning. A first elementary exercise on binary hypothesis testing.

CLASS 2:
First hour: completion of proposed exercise. Second hour: Bayes Tests.

CLASS 3:
First hour: exercise on Bayes Test (Laplacian distributions) Second hour: MiniMax Test.

CLASS 4:
First hour: exercise on Minimax. Second hour: Neyman Pearson Test with example.

CLASS 5:
First hour: ROC properties. NP test with discrete RVs: randomization. Second hour: Exercise on Bayes, Minimax, Neyman-Pearson tests.

CLASS 6:
First hour: Multiple hypothesis testing, Bayesian approach. MAP and ML tests. Decision regions, boundaries among regions: examples in \( \mathbb{R}^1 \) and \( \mathbb{R}^2 \). Second hour: exercise: 3 equally-likely signal "hypotheses" -A,0,A in AWGN noise: Bayes rule (ML) based on the sample-mean (sufficient statistic).

CLASS 7:

CLASS 8:

CLASS 9:

CLASS 10:
Gram-Schmidt orthonormalization. Detailed example. Operations on signals, and dual operations on signal images.

CLASS 11:

CLASS 12:

CLASS 13:

CLASS 14:
Summary of useful matrices: Normals and their subclasses: unitary, hermitian, skew-hermitian. If noise process is white, any ON complete basis is KL. Digital modulation. Example: QPSK. Digital demodulation with correlators bank or matched-filter bank.

CLASS 15:

CLASS 16:
Examples of MAP RX and evaluation of symbol error probability Pe. First hour: MAP RX for QPSK signals and its Pe. Second hour: MAP RX for generic binary signals, basis detector, reduced complexity signal detector. Evaluation of Pe.

CLASS 17:

CLASS 18:
First hour: Calculation of Pe for 16-QAM (end). Second hour: Calculation of Pe for M-ary orthogonal signaling. Begin calculation of Bit error rate (BER).

CLASS 19:

CLASS 20:
Further notes on Gray mapping. Approximate BER calculation: union upper bound, minimum distance bound, nearest-neighbor bound. Lower bounds. Example: M-PSK. Review of cartesian(X,Y)-to-polar(R,Q) probability transformation. For zero-mean normal (X,Y), (R,Q) are independent with Rayleigh and Uniform marginals.

CLASS 21:
For non-zero-mean normal (X,Y), (R,Q) are dependent, with Rice and Bennet marginals. Properties of Rayleigh, Rice, Bennet PDFs. Use of Bennet PDF in the exact evaluation of Pe in M-PSK. Composite hypothesis testing: introduction. Bayesian approach: Example of partially known signals in AWGN.

CLASS 22:
Partially known signals in AWGN: Bayesian MAP decision rule. Application to incoherent reception of passband signals. Optimal incoherent MAP receiver structure.

CLASS 23:
Alternative more compact derivation of incoherent MAP receiver for passband signals using complex envelopes. Incoherent OOK receiver and its BER evaluation.

CLASS 24:
of the discretized signal sample. Example 1: whitening by unitary transformation that aligns the orthonormal eigenvectors of the noise covariance matrix to the canonical basis. Example 2: Cholesky decomposition of covariance matrix and noise whitening. Example of calculation of Cholesky decomposition.

CLASS 25:
Exercise: whitening and Pe evaluation for sampled signals in colored Gaussian noise.

CLASS 26:

CLASS 27:

CLASS 28:
Phase estimation. Proof of CRLB. Extension of CRLB to vector parameters: theorem statement and examples. ML estimation, introduction. If an efficient estimator exists, it is ML.

CLASS 29:
ML: asymptotic properties and invariance. Examples: 1) Gaussian observations with unknown (constant) mean and variance. 2) Linear Gaussian model and comparison with least-squares solution. 3) Phase estimation of passband signals (begin)

CLASS 30:

CLASS 31:

CLASS 32:

CLASS 33:

CLASS 34:
SF theorem: key to proof. Calculation of innovations filter L(z) for real processes through the SF. Regular processes classification with L(z) a rational fraction. AR, MA, ARMA processes. Example: AR(1).

CLASS 35:
CLASS 36: